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Estimating Markups under Nonlinear Pricing Competition

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ABSTRACT

Estimating Markups under Nonlinear Pricing Competition*

by Eugenio J. Miravete and Lars-Hendrik Röller

This paper provides a structural interpretation to the estimates of the shape and position of nonlinear tariffs. We focus on the evaluation of price-cost margins, and thus we need to identify marginal cost from an equilibrium model of nonlinear pricing competition. We estimate these price-cost margins using quarterly data from the early U.S. cellular telephone industry between 1984 and 1988. Our results indicate that the margins are increased under duopoly, due to a significant reduction in marginal costs. Moreover, we find that the price-cost margins vary over the consumption levels and that low end users are subject to higher price-cost margins than high-end users. The impact of competition further increases the margins in the low-end user segment, relative to high end-users. In that sense the benefits of competition, which are largely due to increased efficiencies, are passed on relatively more to high-end users. We also show that these findings are robust even if one includes a number of observable market demand and cost variables.

Keywords: Estimation of Equilibrium Oligopoly Models, Competitive Nonlinear Pricing, Common Agency

JEL Classification: D43, D82, L96

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ZUSAMMENFASSUNG

Schätzung von Preisaufschlägen im nicht-linearen Preissetzungswettbewerb

Dieses Papier bietet eine strukturelle Interpretation der Schätzungen der Form und Position nichtlinearer Tarife. Dabei konzentrieren wir uns auf die Bewertung von Preisaufschlägen und müssen daher zunächst die Grenzkosten in einem Gleichgewichtsmodell nicht-linearen Preiswettbewerbs identifizieren. Wir schätzen diese Preisaufschläge, indem wir Quartalsdaten der jungen Mobilfunkindustrie der U.S.A. zwischen 1984 und 1988 verwenden. Die Ergebnisse deuten darauf hin, dass die Aufschläge in einem Duopol aufgrund signifikanter Grenzkostenreduktion größer sind. Außerdem lässt sich feststellen, dass die Preisaufschläge über die Konsumniveaus variieren und dass Nutzer im Niedrigsegment (‚low-end') höhere Preisaufschläge zu tragen haben als ‚high-end'-Nutzer. Der Einfluß des Wettbewerbs vergrößert noch die Preisaufschläge im ‚low-end'-Bereich im Vergleich zum ‚high-end'. In diesem Sinne profitieren die ‚high-end'-Nutzer mehr vom Wettbewerb, der sich vor allem in gesteigerten Effizienzen positiv niederschlägt. Diese Ergebnisse sind robust, wie gezeigt werden kann, sogar wenn eine Reihe beobachtbarer Marktnachfrage- und Kostenvariablen hinzugefügt wird.

1 Introduction

Nonlinear pricing is a phenomenon that is observed in many markets, such as electricity, gas, and telecommunications. In recent years, many of these markets have undergone a tremendous amount of regulatory and structural changes, raising many issues as to the impact of competition and regulation in markets where firms compete in nonlinear prices. Given its empirical relevance, it is somewhat surprising that are few structural empirical papers that investigate the impact of nonlinear pricing strategies on consumers, firms, and welfare.

This paper describes a structural model of competition, where firms compete in nonlinear prices. In general, nonlinear pricing introduces new issues that are absent in models of uniform pricing. When a firm offers a menu of two-part tariffs, consumers self-select the tariff that is optimal for them. Designing the menu of tariffs according to the distribution of consumers introduces the possibility for a firm to price-discriminate amongst consumer groups. As a result the price–cost margins vary across consumer groups.

In such a setting, competition affects the equilibrium tariff functions in a number of ways. Intuitively, firms not only have to design the tariff function subject to consumers self-selecting a tariff, but also take the tariff function offered by other firms into account. In other words, enforcing consumers' incentive compatibility constraint becomes more complicated since now consumers have the outside option of purchasing from the competitor and not only the possibility of not participating in the market.

In equilibrium, competition affects price cost–margins in a number of ways. If marginal costs and the distribution of consumer types are held constant, price cost margins –as well as profits– decline, while all consumers benefits should increase. However, the impact of competition on price–cost margins varies across consumer groups, which implies that some segments become less profitable than others. As a result, competition can affects consumer groups rather differently. For instance, under nonlinear pricing it is entirely possible that some consumers benefit much more than others. Moreover, when competition is associated with a decline in marginal costs (due to possible efficiency gains) or when the distribution of consumer types changes, then it is possible that price–cost margins increase for some consumer types under competition.

To evaluate such price–cost margins, we need to recover marginal costs. In this sense the approach taken in this paper is in line with other models of empirical industrial organization. We identify marginal costs from an equilibrium model of competition. In this paper we concentrate on identifying marginal costs and investigate price–cost margins. As we will see, there are other structural parameters of importance. These include the distribution of consumer types, as well as the "marginal consumer" (*i.e.*, the consumer that is indifferent between subscribing to a tariff plan or not subscribing at all). In particular, the distribution of consumer types is necessary in order to evaluate consumer surplus or welfare, as one need to integrate over consumer types to arrive at aggregate rents. However, the identification assumptions needed to recover the consumer distribution are substantially more demanding than the ones needed for the identification of marginal costs [see Miravete and Röller, (2003)].

We apply the model to quarterly data from the early U.S. cellular telephone industry between 1984 and 1988. The FCC divided the continental US 302 into non–overlapping regional markets and issued exactly two licenses for each market. The typical situation was that an incumbent (the so–called *wireline*) started operation before a second operator (the *nonwireline*) entered. We thus have a period of monopoly, followed by duopoly. We use this data to study the impact of competition and price–cost margins and marginal costs. Our results indicate that the margins increase under duopoly, due to a significant reduction in marginal costs. Moreover, we find that the price–cost margins vary over the consumption levels and that low end users are subject to higher price–cost margins than high–end users. The impact of competition further increases the margins in the low–end user segment, relative to high end–users. In that sense the benefits of competition, which are largely due to increased efficiencies, are passed on relatively more to high–end users. We also show that these findings are robust even if one includes a number of observable market demand and cost variables.

The paper proceeds as follow. Section 2 describes the basic model, then Section 3 implements it, and Section 4 concludes.

2 A Duopoly Model of Nonlinear Pricing Competition

This section is based largely on Miravete and Röller (2003). Let there be two firms denoted 1 and 2, each offering a service x_1 and x_2. We begin by specifying the demand side and assume that consumers' utility can be characterized by:

$$U(x_1, x_2, \theta_1, \theta_2, \kappa) = \theta_1 x_1 + \theta_2 x_2 - \frac{b_1}{2} x_1^2 - \frac{b_2}{2} x_2^2 + \kappa x_1 x_2, \tag{1}$$

where all parameters except κ are positive, and where θ_1 and θ_2 denote type dimensions accounting for the intensity of preferences of product varieties offered by firm 1 and 2, respectively. When $\kappa < 0$ the two services are substitutes, when $\kappa = 0$ they are independent, and when $\kappa > 0$ then the services are offered by the two firms are complements. If $\theta_1 = \theta_2$ and $b_1 = b_2 = -\kappa$ then x_1 and x_2 are perfect substitutes [see Vives (1999)]. When $x_2 = 0$, this expression defines the preferences under the monopoly period.

The second element of demand specification in models of nonlinear pricing is the joint distribution of consumer types over θ_1 and θ_2. The equilibrium distribution of the "effective" willingness to pay for a particular service is now also affected by the pricing decision of the competing firm. The equilibrium distribution of types will therefore be endogenously determined by the nonlinear tariffs offered by the competing firms and. The sufficient statistic that captures consumers' heterogeneity of preferences for product 1 is:

$$z_1 = \theta_1 + \frac{\kappa \theta_2}{b_2 + \gamma_2}, \tag{2}$$

so that when products are independent (*i.e.*, $\kappa = 0$), competing firms become local monopolists and types need not be redefined.

In order to solve the model in closed–form we assume that z_1 and z_2 have a joint Sarmanov distribution with the following Burr type XII marginals:

$$\theta_i \sim F_i(z_i) = 1 - \left[1 - \frac{z_i - \underline{z}_i}{\overline{z}i - \underline{z}_i}\right]^{1/\lambda_i}, \qquad z_i \in [\underline{z}_i, \overline{z}_i]. \tag{3}$$

For the monopoly case, we simply have a Burr type XII distribution for θ_1, which includes, among others, the uniform distribution as a special case. There are several advantages of using this distribution. First, it allows for general correlation patterns among types. Second, this distribution allows for explicit closed form solution for the pricing problem, for both the monopoly and the duopoly cases. Third, different values of λ_i identify whether high valuation consumers are more or less numerous than low valuation consumers. Thus, given the ratio of high to low valuation customers, firms have to introduce more or less powerful contracts to induce self–selection and thus minimize the informational rents kept by consumers. More or less powerful contracts translate into tariff functions with different degree of concavity. Thus, the distributional assumption (3) allows us to summarize in a single sufficient statistic the degree of concavity of the tariff over the relevant consumption range. Lastly, the optimal markup is increasing on λ_i, and both the markup and the hazard rate of the distribution of z_i can be unequivocally ordered with respect to λ_i. The position and curvature of the lower envelope of tariff options in the data is therefore the key element to identify this parameter .

Given the preferences (1), the distributional assumption (3), and denoting marginal costs by $c_i(Y, \mathbf{W_i})$ –*i.e.*, depending on the overall scale of the market and a vector of input prices–, the optimal tariff is a quadratic function of purchases where the coefficients are nonlinear functions of the structural parameters $c_1, c_2, \lambda_1, \lambda_2, \kappa, b_1, b_2$, while the optimal consumption is linear in the type of consumers.

3 Empirical Implementation

The tariff data we observe is a menu of two–part tariffs for each firm in each market at a point in time. To identify the structural parameters we first specify the following approximation to the menu of two-part tariffs:[1]

$$T_i(x_i) = \alpha_i + \beta_i x_i + \frac{\gamma_i}{2} x_i^2. \tag{4}$$

Given that we have information on the entire menu of two part tariffs, (4) can be estimated by a series of simple OLS regressions as follows. Varying the usage of x_1 and x_2 from 1 to $\mathbb{X}$ (where $\mathbb{X}$ is the maximum consumption level that we fix at 500 minutes given the usage pattern of this market in the 1980s) we can compute the associated minimum tariff, by choosing the tariff that yields the lowest payment for that usage level. Using this data, we can then estimate (4), yielding parameter estimates $\{\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2\}$. Note that this estimation is done for each market at each point in time. We thus obtain reduced from estimates on the shape of the tariff for all observations in our data set.

3.1 Identification

Having obtained reduced form estimates that summarize the shape of the tariff $\{\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2\}$ we next ask what structural parameters can be identified from this information. In other words, our approach does not estimate the structural parameters directly from the first–order conditions using nonlinear techniques, but rather uses the information contained in the reduced form estimates and asks what structural parameters can be solved for.

Overall, there are a total of nine structural parameters $\{c_1, c_2, \lambda_1, \lambda_2, z_1^\circ, z_2^circ, b_1, b_2, \kappa\}$ that characterize the above equilibrium approach and that one needs to identify in order to do a complete

[1] See Miravete and Röller (2003) for a discussion on using a continuous tariff approximation to a menu of two–part tariffs. Basically, if firms offer a menu with a discrete number of options they will not extract the maximum informational rents from consumers. Unless we account for some costs associated with the introduction of an increasing number of tariff options, the equilibrium number of tariff options will never be finite. Indicators related to these billing or marketing costs are not available, and thus, we are not able to modify the model to determine endogenously the optimal number of optional two-part tariffs offered. The main justification for our approach is that the number of options needed to "almost" mimic the continuous solution is quite small. See also Wilson (1993) and Miravete (2003).

equilibrium analysis. These structural parameters characterize the distribution of consumer types (λ_i), the marginal costs (c_i), the marginal consumer (z_i°), the degree of substitutability between the two products (κ), as well as the slope of demands (b_i). However, there are only 6 pieces of information available from the shape of the tariff through $\{\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2\}$.

In general, there are three more pieces of information necessary to identify all the structural parameters of the nonlinear pricing game. To see this, we equate the coefficients of the quadratic approximation to those of the tariff solution of the nonlinear pricing model to obtain: (the relationships for firm 2 are again analogous),

$$c_1 = \beta_1 + \gamma_1 \mathbb{X}, \tag{5a}$$

$$\lambda_1 = \frac{-\gamma_1}{\gamma_1 + \left[b_1 - \dfrac{\kappa^2}{b_2 + \gamma_2} \right]} \geq 0, \tag{5b}$$

$$z_1^\circ = \beta_1 + \frac{\kappa \beta_2}{b_2 + \gamma_2}. \tag{5c}$$

where z_1° is derived from $x_1(z_1^\circ) = 0$, *i.e.*, the consumption for the lowest type is zero, while $\mathbb{X}$ is the maximum consumption. Observe that the identification of λ_1 depends on the curvature of both tariffs through γ_1 and γ_2. This ensures that the nonlinear tariffs are best response to each other, and therefore we make use of the Nash perfection to identify the distributions of types. Identification for the special case of monopoly is obtained by setting $\kappa = 0$.

As can be seen in (3), identification of the structural parameters $\{\lambda_1, \lambda_2, z_1^\circ, z_2^\circ\}$ requires estimates of $\{b_1, b_2, \kappa\}$. Miravete and Röller (2003) obtain estimates of these demand parameters, using a sub–sample of markets where information on the number of subscribers is available. Having made additional identification assumptions to recover the distributional parameters $\{\lambda_1, \lambda_2, z_1^\circ, z_2^\circ\}$ allows the full calculation of all welfare results, such as consumer surplus and profits integrated over the entire range of consumer groups.

By contrast, the identification of marginal costs is relatively straightforward. Since $c_1 = \beta_1 + \gamma_1 \mathbb{X}$, marginal costs are identified by the slope and the curvature of the equilibrium tariff function, as well as by the maximum consumption. In other words, less is needed to recover marginal costs in this equilibrium context, even though without $\{\lambda_1, \lambda_2, z_1^\circ, z_2^\circ\}$, welfare magnitudes are not identifiable.

Below we will concentrate on issues that can be addressed from estimation of marginal costs alone. Moreover, note that identification of price–cost margins is also less demanding. Using the fact that the derivative of the tariff is the price at each usage level, we can derive price–cost markups as a function of consumption from (4) and (5a) as follows:

$$PCM(x_i) = \frac{p_i(x_i) - c_i}{p_i(x_i)} = \frac{\gamma_i\,(\mathbb{X} - x_i)}{\beta_i + \gamma_i x_i}. \tag{6}$$

where a similar expression holds for the other firm. Note that the PCM of each firm varies with consumption, going towards zero as consumption approaches the maximum.

3.2 Estimates of Price-Cost Margins

We are now ready to investigate the price–cost margins and how they are affected by the introduction of a second competitor. Using the estimates of the tariff functions (4), Table 1 reports the average PCM for the monopoly and duopoly periods. Note that we have restricted ourselves to three consumption levels, namely 50 minutes (low), 250 minutes (medium), and 450 minutes (high).

We have assumed that the maximum consumption is 500 minutes (i.e. $\mathbb{X} = 500$). This choice of maximum consumption was made after studying aggregate statistics of cellular telephone usage in the mid 1980s. Individual data on consumption is not available, and an airtime of 500 minutes is well above the average monthly usage of 200 minutes at this time.

As can be seen, the price–cost margins are declining in the usage levels, ranging from 13.6% for low consumption, over 9.3% for medium, to 2.4% for high consumption in the monopoly period. This implies that the markups vary considerably across users. Interestingly, the price–cost margins under duopoly vary even more and are generally, ranging from 19.6%, over 13.1% to 3.4% for the respective consumption levels. At first glance it thus appears that competition leads to higher price–cost margins across consumption levels. Before interpreting this finding further, it should be noted that the comparisons in Table 1 are not controlled for other exogenous demand and cost factors, which may have varied across markets and may explain markups.

Table 1 also reports the estimated marginal costs, which is found to be on average 63 cents under monopoly and 58 cents under duopoly. In other words, marginal costs drop significantly due to the introduction of competition. On the other hand, prices are much less affected by entry (see Table 1 again), even though they are lower under duopoly. For example, at low usage levels prices are essentially the same, while at the very high end of consumption marginal rates drop from 64 cents per minute to 60 cents per minute. Overall, it appears that price–cost margins increase under duopoly because marginal costs have come down considerably more than prices.[2]

3.3 Relating Price–Cost Margins to Market Characteristics

To further control for exogenous changes, we report OLS estimates, where we regress the estimated price–cost margins on observable demand and cost characteristics. Table 2 provides summary statistics and defines the variables used in the analysis. Essentially, we have three types of exogenous variables that are used in the regressions below. First, there are demand side variables such as number of business, age of the market, population, average commuting time in the market, and growth of the population. Second, we have cost variables such as cost of energy, prime lending rate, wage index in the telecommunications sector, average rent of a square foot of office space, and an index of operating cost of offices. In addition, the variables DUO is an indicator of entry, and TREND is controlling for changes over time.

Table 3 presents the estimation results of markups on these observed market characteristics at three usage levels (50, 250, and 450 minutes of consumption, respectively). As can be seen, the

[2] Since other factors might be driving the development of price-cost margins (such as demand and cost conditions), we have also checked the change in price–cost margins and marginal costs at the actual time of entry. More precisely, we consider the last quarter where a particular market is a monopoly and compare this to the first quarter of duopoly. In other words, we compare two subsequent quarters, where the event of entry has occurred in the second quarter. The results are such that prices are hardly affected by entry, while marginal costs drop significantly from $0.617 to $0.576.

impact on competition is to increase the price–cost margins. In particular, the coefficient on duo indicates that the price–cost margins for the low end users (50 minutes of consumption) increased by 3.9%. Moreover, this is statistically significant (t–stat of 2.35). For the medium and high–end users, we also find that price–cost margins increase significantly, although the increase is smaller than for the low end customers. Specifically, medium users yield a 2.5% increase in margins, while high end users are subject to only 0.6% increase in margins. In this sense, competition increase margins more for low end users than for high end users.

It should be noted that the results in Table 3 are broadly in line with the descriptive findings in Table 1, although the impact of competition on all margins is lower, once we have controlled for other observable market characteristics.

The estimates in Table 3 further imply a negative and statistically very significant time trend on margins across all usage levels. For example, the price–cost margin for low end users falls on average 3.9% per quarter. This is almost as much as in the quarter when entry occurred, suggesting that the reduction in margins is roughly doubled when entry occurs.

Regarding the exogenous demand variables we find that many demand side variables are significantly related to margins (see Table 3). For example, more high potential business establishments (BUSINESS) and population growth (GROWTH) both raise margins significantly across all users, while an increase in the time of commuting lowers margins. Interestingly, the age of the market further increase margins, indicating that mature markets charge higher markups (even though there is a general downward trend on markups).

In terms of the exogenous cost variables, we find that these variables are generally associated with lower margins, which is line with intuition (except for wages). Furthermore, Table 3 also reports on the marginal cost estimates. As can be seen, competition has a significant impact on marginal costs. Specifically, marginal costs are reduced by 4 cents, which is roughly in line with the descriptive results obtained in Table 1. Moreover, there is no statistically significant time trend, indicating that this is a one–time sustainable reduction in marginal costs that occurs at the time of entry.

Overall, the results in Table 3, which are controlled for a number of observable demand and cost factors, are very consistent with the more descriptive results of Table 1. In sum, our results indicate that the margins are increased under duopoly, due to a significant reduction in marginal costs. Moreover, we find that the price–cost margins vary over the consumption levels and that low end users are subject to higher price–cost margins than high end users. The impact of competition further increases the margins in the low end user segment, relative to high end users. In that sense the benefits of competition, which are largely due to increased efficiencies, are passed on relatively more to high end users.

4 Conclusion

This paper introduces a structural model of competition, where firms compete in nonlinear prices. In general, nonlinear pricing introduces new issues that are absent in models of uniform pricing. When a firm offers a menu of two–part tariffs, consumers selfs-select the tariff that is optimal for them. Designing the menu of tariffs according to the distribution of consumers introduces the possibility for a firm to price–discriminate amongst consumer groups. As a result the price–cost margins vary across consumer groups.

To evaluate such price–cost margins, we identify marginal cost from an equilibrium model of competition. In this paper we have concentrated on identifying marginal costs, even though there are other structural parameters of importance, such as the distribution of consumer types, which would allow the evaluation of consumer surplus or welfare (see Miravete and Röller, 2003).

We apply the model to quarterly data from the early U.S. cellular telephone industry between 1984 and 1988. Our results indicate that the margins are increased under duopoly, due to a significant reduction in marginal costs. Moreover, we find that the price–cost margins vary over the consumption levels and that low end users are subject to higher price-cost margins than high-end users. The impact of competition further increases the margins in the low-end user segment, relative to high end-users. In that sense the benefits of competition, which are largely due to increased efficiencies, are passed on relatively more to high end users.

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Table 1
Markups, Prices, Tariffs and Marginal Costs

	minutes	50	250	450
Monopoly Markets	(p-c)/p	0.136	0.093	0.024
	P(x)	0.748	0.695	0.642
	T(x)	46.17	123.93	196.29
	c	0.629	0.629	0.629
Duopoly Markets	(p-c)/p	0.196	0.131	0.034
	P(x)	0.748	0.675	0.602
	T(x)	38.34	115.29	184.41
	c	0.584	0.584	0.584

All money-valued magnitudes are in dollars.

Table 2
Summary Statistics of Market Characteristics

	Mean	Minimum	Maximum
MARKET	38.378	1.000	99.000
YEAR	868.205	844.000	883.000
DUO	0.344	0.000	1.000
TREND	9.778	1.000	16.000
BUSINESS	48.924	7.489	394.436
AGE	19.666	1.000	46.000
POP	2.288	0.336	14.990
COMMUTE	26.238	20.900	36.500
GROWTH	1.164	-0.600	3.599
ENERGY	0.509	-0.362	1.046
PRIME	9.474	7.750	11.000
WAGE	1.938	1.344	2.711
RENT	2.758	2.013	3.589
OPERATE	1.849	0.989	2.608

There are 730 observations. Variables are defined as follows (see Miravete and Röller (2003) for details): market = market identifier, year = year/month of observation, duo = dummy indicating duopoly markets, trend = a time trend in month, business = number of high potential business establishments (in thousands), age = age of the market in months, pop = population of SMSA in millions, commute = average commuting time in minutes, growth = average % growth of population, in the 1980's, energy = state average electricity prices in dollars per kilwatt/hour (in logs), prime = one-year lagged prime lending rate (reflecting the costs of financing cellular equipment), wage = index of average annual wages per employee in the cellular industry (in logs), rent = index of average monthly rent per square foot (in logs), and operate = index of operating expenses (in logs).

Table 3 - Relating Price-Cost Margins to Observables

	Price-cost margin at 50 minutes		Price-cost margin at 250 minutes		Price-cost margin at 450 minutes		Marginal costs (c)	
	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
INTERCEPT	1.262	5.50	0.862	5.31	0.228	5.01	-0.102	-0.62
DUO	0.040	2.35	0.025	2.10	0.006	1.86	-0.038	-3.29
TREND	-0.031	-5.93	-0.021	-5.86	-0.006	-5.74	0.003	0.91
BUSINESS	0.001	2.94	0.001	3.63	0.000	4.50	-	-
AGE	0.005	4.25	0.004	4.37	0.001	4.49	-	-
POP	-6.73E-7	-0.12	-28E-6	-0.72	-1.66E-6	-1.52	-	-
COMMUTE	-0.013	-3.83	-0.010	-4.02	-0.003	-4.19	-	-
GROWTH	0.017	2.75	0.012	2.70	0.003	2.50	-	-
ENERGY	-0.105	-2.70	-0.071	-2.60	-0.018	-2.32	0.040	1.45
PRIME	-0.059	-3.28	-0.039	-3.06	-0.010	-2.75	0.022	1.73
WAGE	0.089	2.57	0.056	2.31	0.013	1.83	0.127	5.07
RENT	-0.086	-2.37	-0.058	-2.25	-0.014	-1.93	-0.014	-0.57
OPERATE	0.030	0.63	0.026	0.80	0.009	0.94	0.143	4.37

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